Rationale for Addressing Unifying Themes/Big Ideas of Science in the Tri-State Science Assessment

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The conceptual approach of the NECAP Science Assessment is supported by recommendations of the National Research Council (NRC) for designing science assessments to satisfy the No Child Left Behind Act. The NRC, located in Washington, is a division of the congressional chartered National Academies, which provides research for the government, scientists, engineers, and the public. A recent article, "NRC Weighs in on States' Science Assessments" (www.edweek.org, published: July 13, 2005) describes a committee of testing experts and university researchers convened by the research council to produce the report, 'Systems for State Science Assessment.' The authors of the report say "the tests should be built around 'organizing principles' or "big ideas" of science, such as evolution and molecular theory, to give students a stronger sense of how different aspects of the discipline connect."

Organizing curriculum and assessment around the unifying themes, or big ideas, of science is not a new idea. References to big ideas of science appear in many national science standards documents written in the 1990s. The American Association for the Advancement of Science describes it this way: "Some powerful ideas often used by mathematicians, scientists, and engineers are not the intellectual property of any one field or discipline. Indeed, notions of system, scale, change and constancy, and models have important applications in business and finance, education, law, government and politics, and other domains, as well as in mathematics, science, and technology. These common themes are really ways of thinking rather than theories or discoveries" (AAAS, 1993, page 261).

Unifying Themes represent the key organizing concepts that pervade science education, crossing traditional science domain boundaries and making up the inquiry tools that scientists use to better investigate and understand phenomena (*NAEP Science Framework*, 1994). Statements of Enduring Knowledge represent the fundamental knowledge of the domains of science. "They are called 'enduring' because they contain essential ideas that students need to internalize and retain in order to achieve science literacy" (*Grade Expectations for VT's Framework of Standards and Learning Opportunities*, 2004). The Tri-State Science Assessment Targets integrate six Unifying Themes/Big Ideas of Science with Statements of Enduring Knowledge for the domains of Life Science, Earth/Space Science, and Physical Science. The Unifying Themes/Big Ideas listed below are further described on the pages that follow.

- **Scientific Inquiry**
- **Nature of Science**
- **Systems and Energy**
- **Models and Scale**
- **Patterns of Change**
- **Form and Function**

"Scientific Inquiry (INQ) is more complex than popular conceptions would have it. It is, for instance, a more subtle and demanding process than the naive idea of "making a great many careful observations and then organizing them." It is far more flexible than the rigid sequence of steps commonly depicted in textbooks as "the scientific method." It is much more than just "doing experiments," and it is not confined to laboratories. More imagination and inventiveness are involved in scientific inquiry than many people realize, yet sooner or later strict logic and empirical evidence must have their day." (AAAS, 1993)

The Inquiry focus in the Tri-State Assessment will be on the ability to question, hypothesize, predict, design and critique investigations, conduct investigations, use science tools and techniques, collect, organize, and interpret/analyze data, use evidence to draw conclusions, develop explanations, and communicate understanding.

Nature of Science (NOS) "Generalizations about how the scientific enterprise operates would be empty without concrete examples. Consider, for example, the proposition that new ideas are shaped by the context in which they are conceived; are often rejected by the scientific establishment; sometimes spring from unexpected findings; and usually grow slowly, through contributions from many different investigators. Without historical examples, such generalizations would be no more than slogans, however well they might be remembered." (AAAS, 1993)

The Nature of Science focus in the Tri-State Assessment will be on the use of tools and technology, how fundamental theories change when applying new evidence and reasoning, how scientists build on the work of others, and attitudes and dispositions of science (e.g., avoiding bias, divergent ideas, healthy skepticism).

Systems and Energy (SAE) "One of the essential components of higher-order thinking is the ability to think about a whole in terms of its parts and, alternatively, about parts in terms of how they relate to one another and to the whole… If these can be specified quantitatively, a computer simulation of the system might be run to study its theoretical behavior, and so provide a way to define problems and investigate complex phenomena" (AAAS, 1993). The concept of energy, which cuts across all fields of the natural sciences and technology, is often used to analyze how systems function. As described in *Benchmarks for Science Literacy*, "Most of what goes on in the universe--from exploding stars and biological growth to the operation of machines and the motion of people–involves some form of energy being transformed into another." (AAAS, 1993)

The Systems and Energy focus in the Tri-State Assessment is on order & organization, interactions, interdependence, equilibrium, energy transfer, and cycles.

Models and Scale (MAS) "Models can be physical, mathematical, or conceptual. They are very effective tools for learning about the things they are intended to resemble. Physical models (such as model rockets) are the most obvious to children. Whether models are physical, mathematical, or conceptual, their usefulness as an instructional device lies in suggesting how things either do work or might work. The more sophisticated concept has to do with the effect of changes in scale. Specifically, the way things work may change with scale." University of Texas at Austin. Mission to Mars: Project Based Learning [On-line] Available: http://www.edb.utexas.edu/missiontomars/unify.html).

The Models and Scale focus in the Tri-State Assessment is on evidence and explanations through models, proportions, magnitude, relationships, and relativity.

Patterns of Change (POC) "Much of science and mathematics has to do with understanding how change occurs in nature and in social and technological systems, and much of technology has to do with creating and controlling change. Constancy, often in the midst of change, is also the subject of intense study in science…. Somewhat different aspects of constancy are described by the terms stability, conservation, equilibrium, steady state, and symmetry. These various ideas are interrelated in some subtle ways." (AAAS, 1993)

The Patterns of Change focus in the Tri-State Assessment is on cycles, constancy and change, and evolutionary change.

Form and Function (FAF) "Form and function are complementary aspects of objects, organisms, and systems in the natural and designed world. The form or shape of an object or system is frequently related to use, operation, or function. Function frequently relies on form. Understanding of form and function applies to different levels of organization. Students should be able to explain function by referring to form and explain form by referring to function." (NRC, 1996)

The Form and Function focus in the Tri-State Assessment is on understanding form and function in the natural world. While form and function in the designed world may be included as it relates to other targets that address technology, *form and function as it relates to engineering design will be assessed locally.*

<table>
<tr><td colspan="6">Table 1.1:
Conceptual Matrix - Developing/Prioritizing Assessment Targets for Tri-State Science Assessment</td></tr>
<tr><td colspan="6">Unifying Themes/Big Ideas of Science
(Subheadings under each Unifying Theme/Big Idea suggest but are not limited to what might be addressed,)</td></tr>
<tr><th>Scientific Inquiry</th><th>Nature of Science</th><th>Systems & Energy</th><th>Models & Scale</th><th>Patterns of Change</th><th>Form & Function</th></tr>
<tr>
<td>• Collect data
• Communicate understanding & ideas
• Design, conduct, & critique investigations
• Represent, analyze, & interpret data
• Experimental design
• Observe
• Predict
• Question and hypothesize
• Use evidence to draw conclusions
• Use tools, & techniques</td>
<td>• Accumulation of science knowledge (evidence & reasoning, looking at work of others)
• Attitudes and dispositions of science (avoiding bias, divergent ideas, healthy skepticism)
• History of Science
• Science/Tech/ Society
• Scientific Theories</td>
<td>• Cycles
• Energy Transfer
• Equilibrium
• Interactions
• Interdependence
• Order & Organization</td>
<td>• Evidence provided through…
• Explanations provided through…
• Relative distance
• Relative sizes

Models include - experimental models, simulations, & representations used to demonstrate abstract ideas</td>
<td>• Constancy and Change
• Cycles
• Evolutionary Change</td>
<td>• Natural World
• Designed World</td>
</tr>
<tr><td colspan="6">Tri-State Assessment targets are written to:
(1) be general enough to allow for multiple potential test items/assessment tasks with varying cognitive demands addressing each assessment target; and
(2) have a cognitive demand (DOK) "ceiling" generally consistent with (Webb's descriptions of) Strategic Thinking (Level 3) – requiring reasoning, planning, using/citing evidence, explaining/justifying thinking, drawing conclusions from data/observations, developing a logical argument for concepts, explaining phenomena in terms of concepts, or solving problems with more than one possible answer OR Skills and Concepts (Level 2) – classify, organize, make observations, compare data, explain relationships, describe examples/non-examples, interpret information.</td></tr>
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